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A High Order Volume Penalty Method

The volume penalty method provides a simple, efficient approach for solving the incompressible Navier-Stokes equations in domains with boundaries or in the presence of moving objects. Despite the simplicity, the method suffers from poor convergence in the penalty parameter, thereby restricting accuracy of any numerical method. We demonstrate that one may achieve high order accuracy by altering the form of the penalty term. We discuss how to construct the modified penalty term, and then provide 2D numerical examples demonstrating improved convergence for the heat equation and Navier-Stokes equations. In addition, we show that modifying the penalty term does not significantly alter the time step restriction from that of the conventional penalty method.